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Chen

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(54) **STREAMLINED DELIVERY OF VIDEO CONTENT**

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H04L 65/612 (2022.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04L 65/4084*** (2013.01); ***H04L 65/608*** (2013.01); ***H04L 65/80*** (2013.01);
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(58) **Field of Classification Search**
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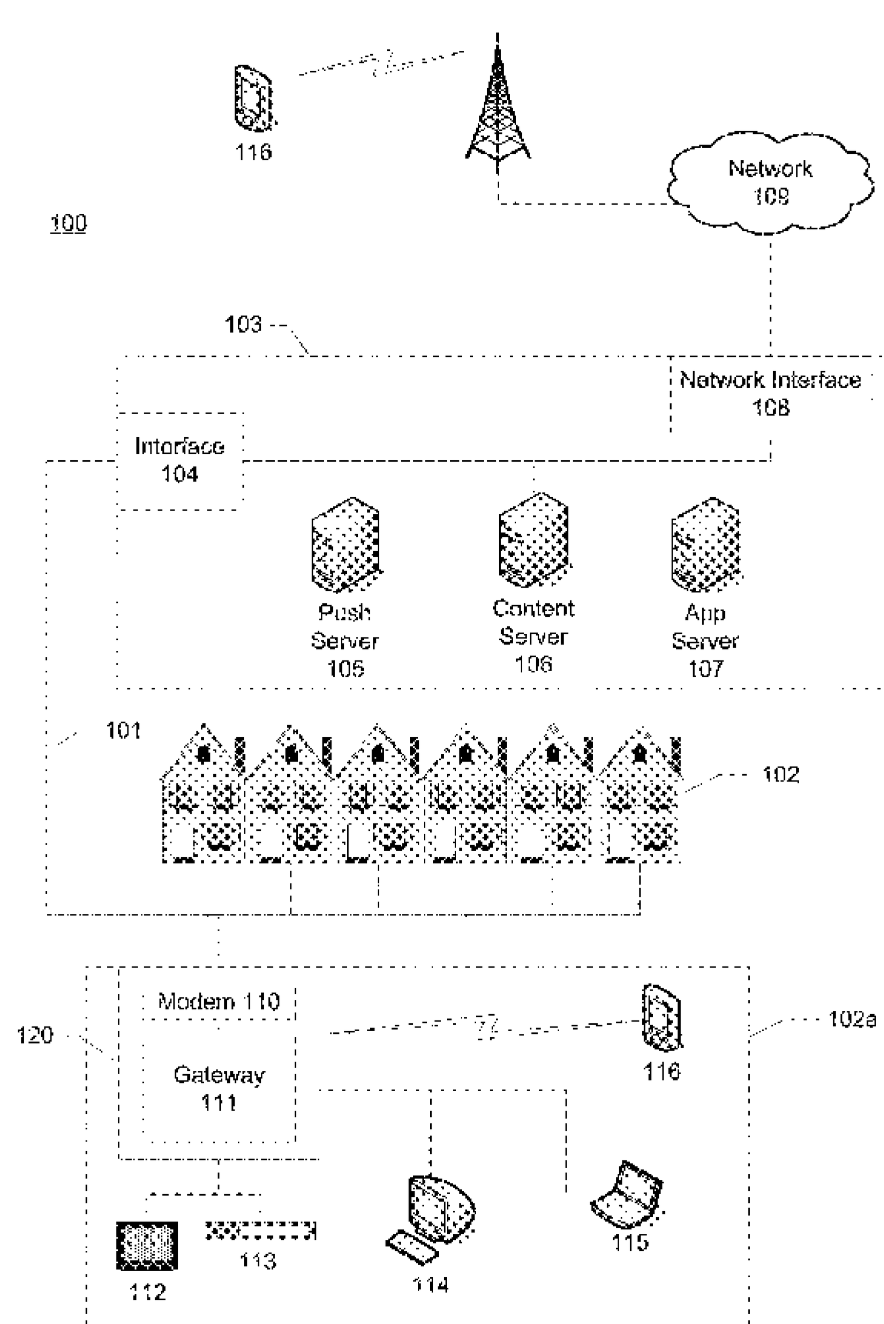
(57) **ABSTRACT**

A content delivery server may provide content to a requesting client device using a streamlined HTTP enhancement proxy delivery technique. For example, an HTTP proxy server may receive a request for video content or a fragment of video content from a client device. The request may be associated with a timeout scheduled to occur if no content has been received after a specified amount of time. The server may then transmit a request for the content to a remote server, such as an upstream cache server in the proxy server's CDN. When the proxy server receives a portion of the requested content from the remote server, the proxy server begins transmitting the portion to the client device before the requested content has been completely received and buffered. The client device may then begin receiving data from the proxy server before timeout has occurred.

33 Claims, 6 Drawing Sheets



(51) **Int. Cl.**
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H04L 65/80 (2022.01)
H04N 21/222 (2011.01)
H04N 21/231 (2011.01)
H04N 21/6587 (2011.01)
H04N 21/845 (2011.01)
H04L 67/568 (2022.01)

(52) **U.S. Cl.**
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(58) **Field of Classification Search**
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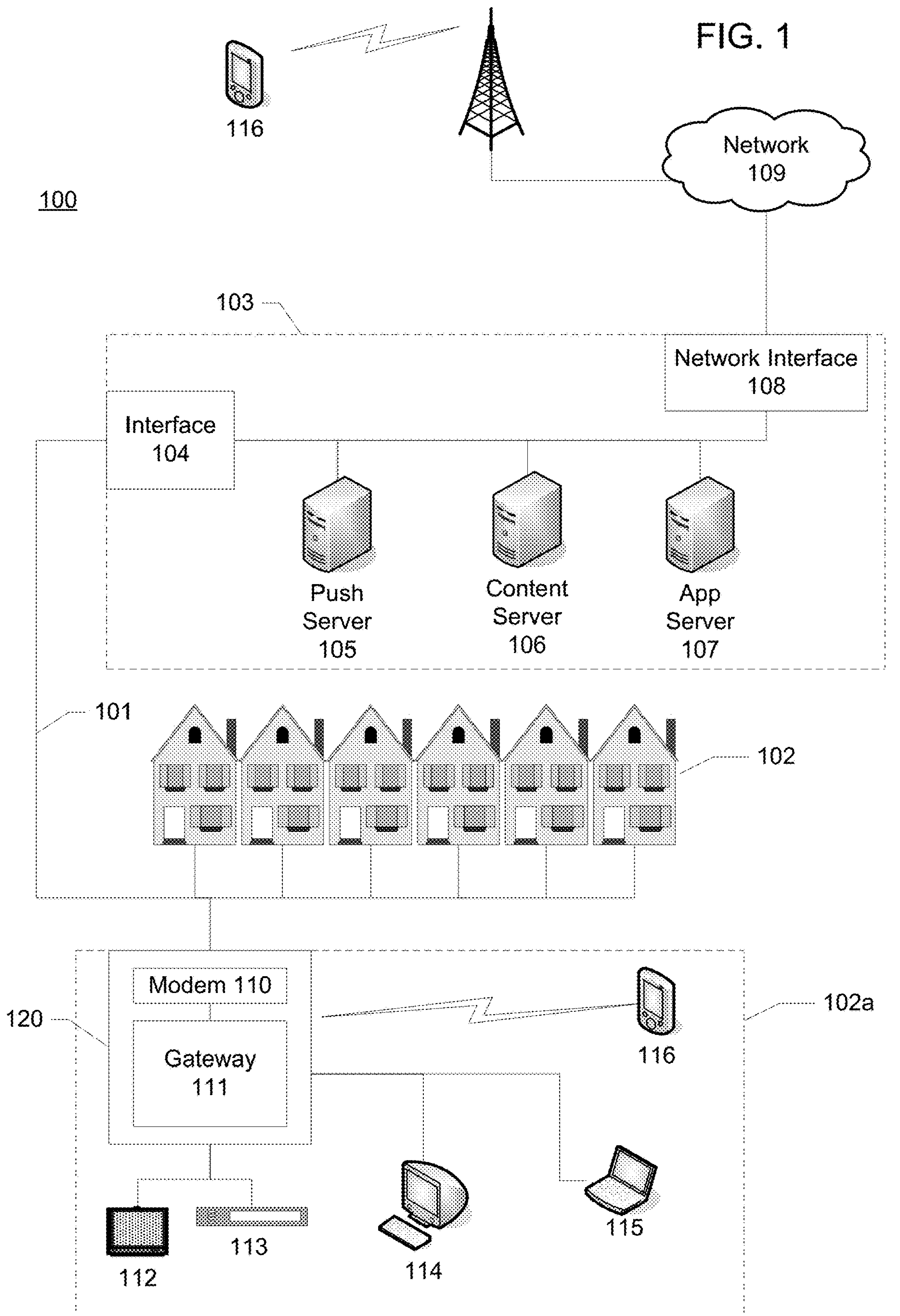


FIG. 1
116
Network
109
100
103
Network Interface
108
Interface
104
Push
Server
105
Content
Server
106
App
Server
107
101
102
Modem 110
Gateway
111
120
116
102a
112
113
114
115

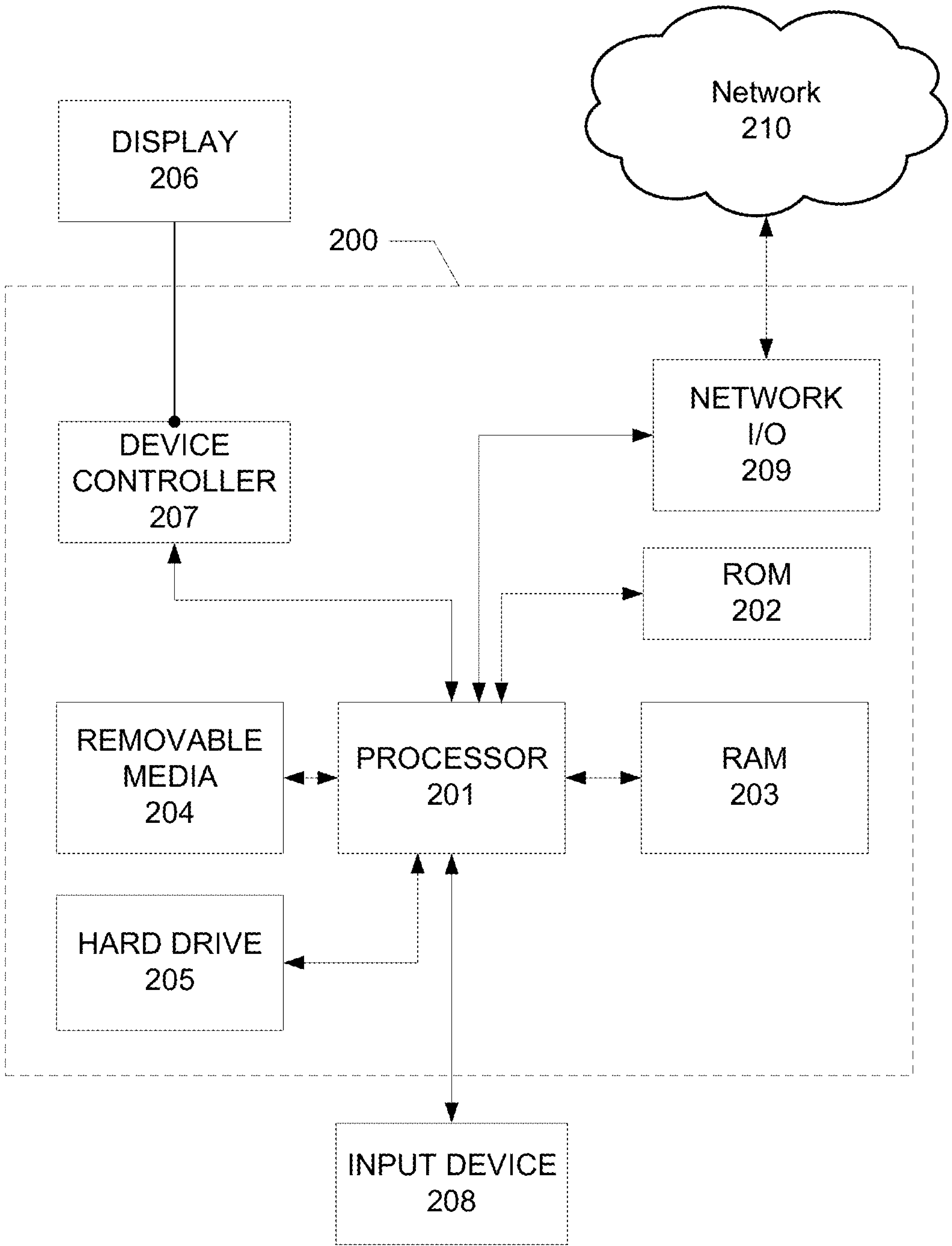

Network
210
DISPLAY
206
200
NETWORK
I/O
209
DEVICE
CONTROLLER
207
ROM
202
REMOVABLE
MEDIA
204
PROCESSOR
201
RAM
203
HARD DRIVE
205
INPUT DEVICE
208

FIG. 2

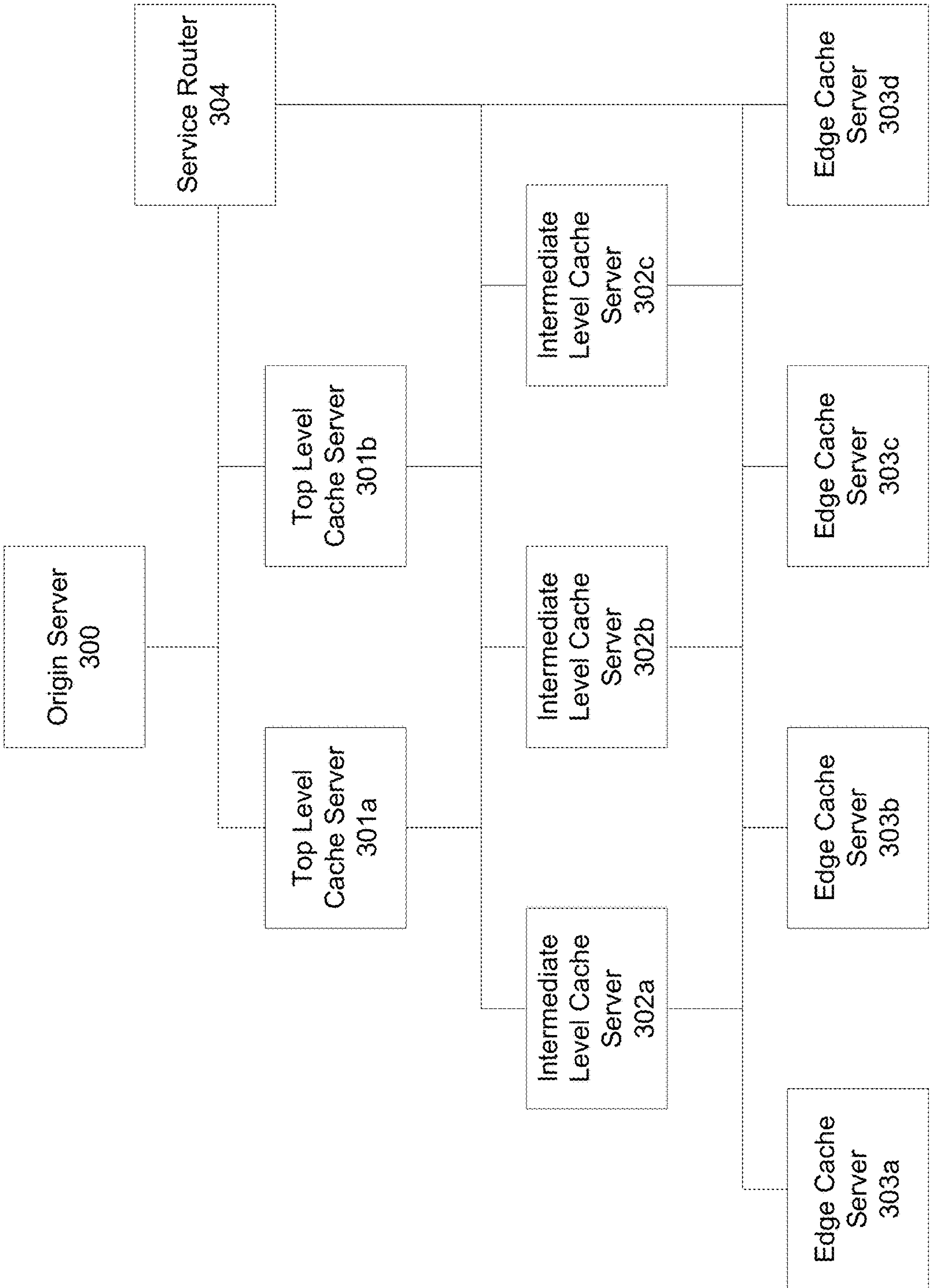

Service Router 304
Origin Server 300
Top Level Cache Server 301a
Top Level Cache Server 301b
Intermediate Level Cache Server 302a
Intermediate Level Cache Server 302b
Intermediate Level Cache Server 302c
Edge Cache Server 303a
Edge Cache Server 303b
Edge Cache Server 303c
Edge Cache Server 303d

FIG. 3a

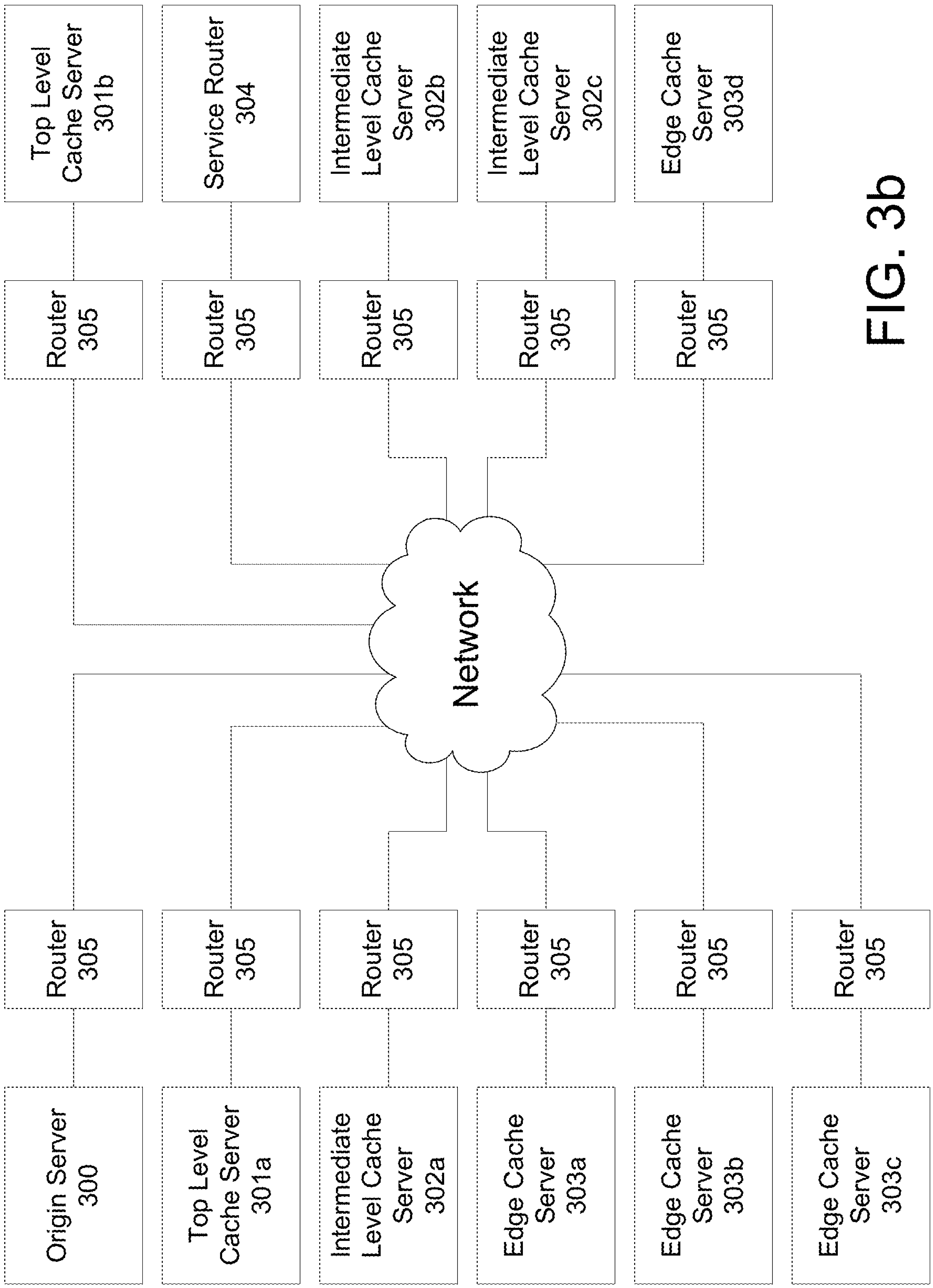

Origin Server 300
Top Level Cache Server 301a
Intermediate Level Cache Server 302a
Edge Cache Server 303a
Edge Cache Server 303b
Edge Cache Server 303c
Router 305
Router 305
Router 305
Router 305
Router 305
Router 305
Network
Router 305
Router 305
Router 305
Router 305
Router 305
Top Level Cache Server 301b
Service Router 304
Intermediate Level Cache Server 302b
Intermediate Level Cache Server 302c
Edge Cache Server 303d

FIG. 3b

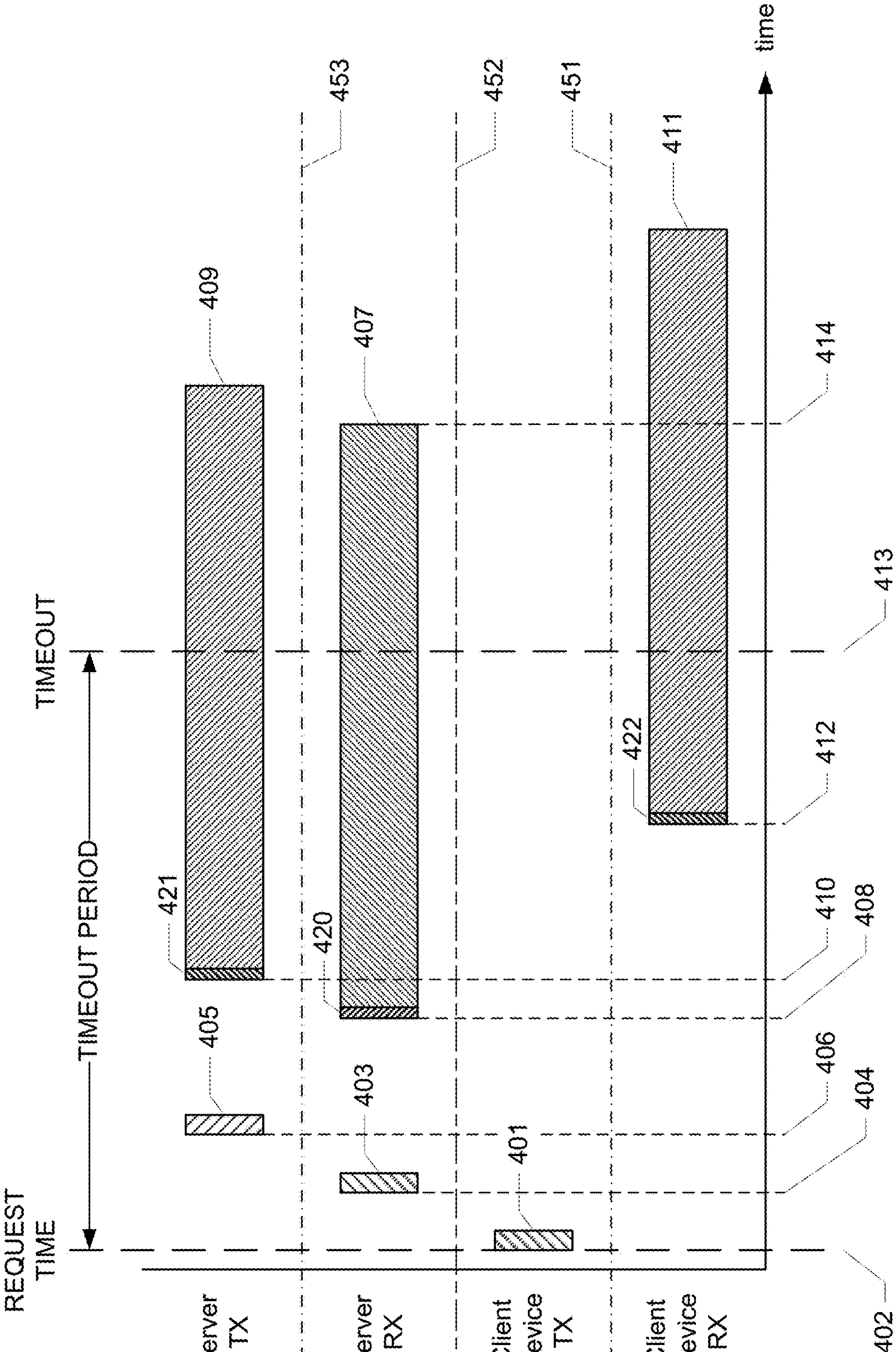
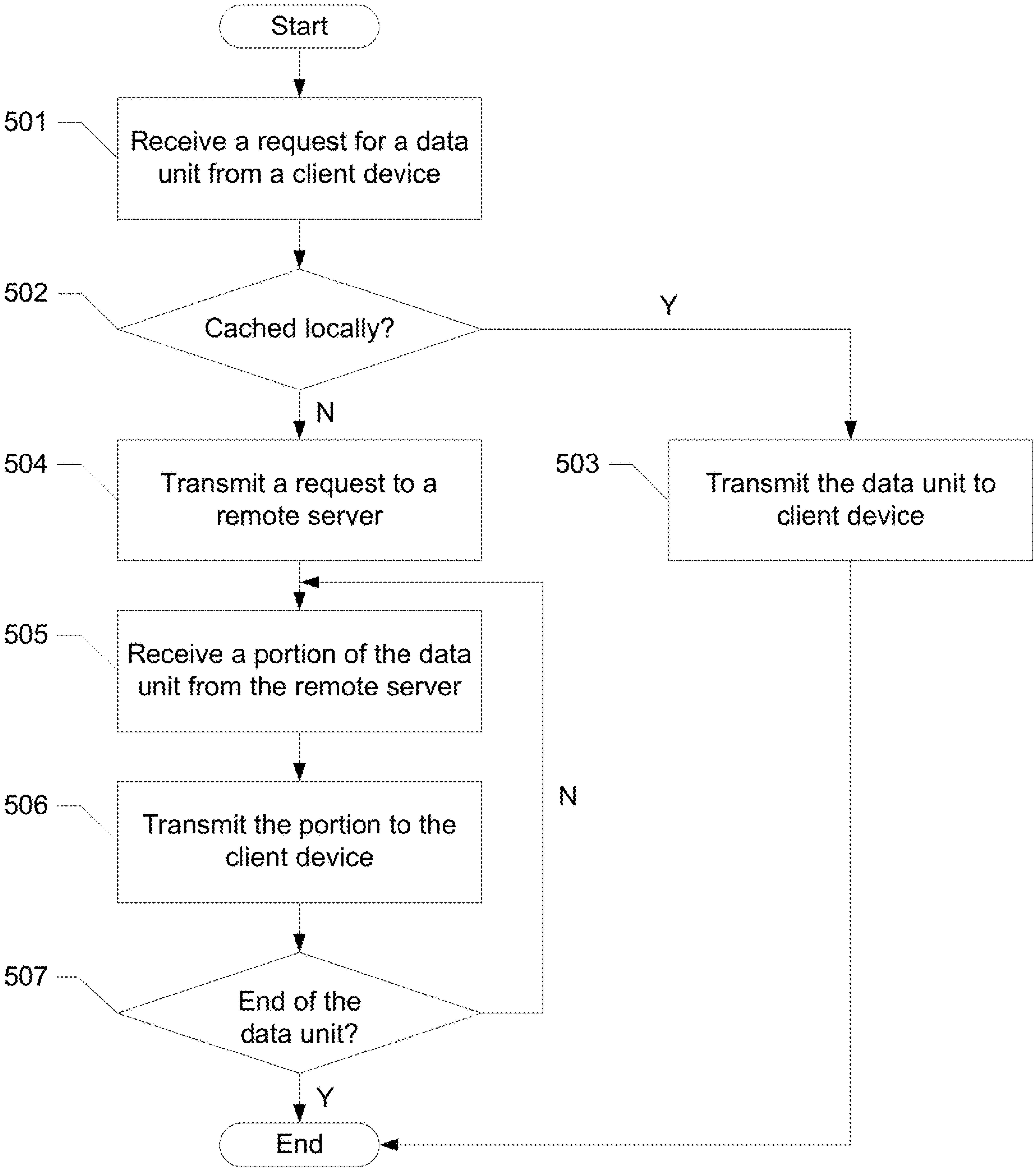

REQUEST TIME
TIMEOUT PERIOD
TIMEOUT
time
Server TX
Server RX
Client Device TX
Client Device RX
401
402
403
404
405
406
407
408
409
410
411
412
413
414
420
421
422
451
452
453

FIG. 4



Start
501
Receive a request for a data unit from a client device
502
Cached locally?
Y
N
504
Transmit a request to a remote server
503
Transmit the data unit to client device
505
Receive a portion of the data unit from the remote server
N
506
Transmit the portion to the client device
507
End of the data unit?
Y
End

FIG. 5

STREAMLINED DELIVERY OF VIDEO CONTENT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of co-pending U.S. application Ser. No. 13/344,674 filed Jan. 6, 2012, titled Streamlined Delivery of Video Content. The contents of application Ser. No. 13/344,674, in their entirety, are incorporated by reference herein.

BACKGROUND

Content delivery networks (CDNs) provide content, such as video content, to users. The CDNs typically employ a hierarchy of computer servers, with an origin server that originally supplies the content, and a hierarchy of proxying servers, caching servers or both organized hierarchically below the origin server to help distribute the content and reduce the load on the origin server.

When a user requests content, such as a particular video, the user's client device (e.g., computer, cell phone, internet-enabled television set) may transmit a request for a fragment of the user-requested content, such as a two-second video fragment, to a proxy server using Hypertext Transfer Protocol (HTTP). The proxy server can provide the fragment if it is available, and if it is not, the proxy server can transmit a request to another proxy server that is higher up in the content's hierarchy, and the process can repeat further up the hierarchy until a server having the requested fragment is reached (or until the source is reached). When the proxy server receives the fragment from the higher level server, the proxy server waits until it possesses the entire content fragment before transmitting data to the client device. This process repeats until all fragments of the user-requested content have been received by the client device.

Content requests are often associated with a timeout, a specified period of time that is allowed to elapse before the request is to be retransmitted or abandoned if none of the requested content has been received. When the user requests high bit rate content, such as a high-definition television content, the request may timeout if the proxy server cannot cache and then deliver the requested content in time. In response to the request timeout, the client device may abandon the request or transmit a redundant request for the content, often at a lower bit rate, which can result in network overload and other bandwidth inefficiencies. In either case, the user's viewing experience is negatively impacted by lower quality content, or no content at all, being delivered to the user's device. In the context of CDNs, where multiple servers are used to deliver content, these inefficiencies are escalated because servers at each level of the CDN hierarchy may be respectively transmitting multiple requests for the same content as a result of timeout.

Accordingly, there remains an ever-present need to improve the delivery of content, and to balance that need with the strains on the network.

SUMMARY

Some features described herein relate generally to allowing a client device to request content from a computing device, such as a proxy server, and receive data from the computing device before timeout of the request has occurred. Some disclosed aspects relate to streamlined caching (also referred to as progressive caching), where data transmission by a proxy server to a client device begins before it has been completely received by the proxy server from another server. As a result, timeout of a content request may be avoided, allowing a client or user device to receive and provide high data rate content, such as HD or 3D video or video fragments, to the requesting user.

In an embodiment, a server may receive an HTTP request for content, such as a data unit, from a client device, such as a gateway device coupled to a user's video display (e.g., computer monitor, television set, smart phone, etc.). The data unit may be, for example, content such as a video or a fragment of a video requested by a user, (e.g., a two-second video fragment). The server may determine that it does not possess the requested content and transmit a request for the content to a remote server, such as an upstream cache server in the server's CDN. The server may begin receiving the requested content from the remote server and buffer a portion of the received content. The portion of the content may be, for example, the first several bytes of a multi-megabyte data transmission. In another example, the portion of the content may be based on a maximum transmission unit or a smallest bufferable data unit. The server may then transmit the portion of the content to the requesting user device, in advance of completely receiving and storing the requested content from the remote server.

In some embodiments, the server may receive data from, and transmit data to, one or more intermediate devices. For example, the server may receive a content request from a modem coupled to or embedded within the client device. In another example, the server may transmit a content request to a service router, which may appropriately route communications to and from the remote server.

In some embodiments, the server may identify the remote server based on a server selection technique, a path selection technique, or both. For example, the server may search a cache server index to identify a remote server that possesses the requested content. The search may be based on address information extracted from a content request, such as a uniform resource identifier (URI) or URI prefix for the requested content.

In some embodiments, the server may identify a communications path for communications with the remote server. For example, the server may perform path selection based on a longest match lookup routine, where the remote server that possesses the longest match of the address information for the requested content is selected.

This summary is not intended to identify critical or essential features of the disclosures herein, but instead merely summarizes certain features and variations thereof. Other details and features will also be described in the sections that follow.

BRIEF DESCRIPTION OF THE DRAWINGS

Some features herein are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements.

FIG. **1** illustrates an example network.

FIG. **2** illustrates an example software and hardware platform on which various elements described herein can be implemented.

FIG. **3***a* illustrates an example logical hierarchy for a content delivery network, and FIG. **3***b* illustrates an example physical arrangement for the hierarchy.

FIG. **4** illustrates an example timeline for a streamlined content delivery technique.

FIG. **5** illustrates an example process flow for providing content using a streamlined content delivery technique.

DETAILED DESCRIPTION

FIG. **1** illustrates an example information distribution network **100** on which many of the various features described herein may be implemented. Network **100** may be any type of information distribution network, such as satellite, telephone, cellular, wireless, etc. One example may be a wireless network, an optical fiber network, a coaxial cable network or a hybrid fiber/coax (HFC) distribution network. Such networks **100** use a series of interconnected communication links **101** (e.g., coaxial cables, optical fibers, wireless links, etc.) to connect multiple homes **102** or other user locations to a local office or headend **103**. The local office **103** may transmit downstream information signals onto the links **101**, and each home **102** may have a receiver used to receive and process those signals.

There may be one link **101** originating from the local office **103**, and it may be split a number of times to distribute the signal to various homes **102** in the vicinity (which may be many miles) of the local office **103**. Although the term home is used by way of example, locations **102** may be any type of user premises, such as businesses, institutions, etc. The links **101** may include components not illustrated, such as splitters, filters, amplifiers, etc. to help convey the signal clearly, but in general each split introduces a bit of signal degradation. Portions of the links **101** may also be implemented with fiber-optic cable, while other portions may be implemented with coaxial cable, other lines, or wireless communication paths.

The local office **103** may include interface **104**, such as a cable modem termination system (CMTS), which may be a computing device configured to manage communications between devices on the network of links **101** and backend devices such as servers **105-107** (to be discussed further below). The CMTS may be as specified in a standard, such as, in an example of an HFC-type network, the Data Over Cable Service Interface Specification (DOCSIS) standard, published by Cable Television Laboratories, Inc. (a.k.a. CableLabs), or it may be a similar or modified device instead. The CMTS may be configured to place data on one or more downstream channels or frequencies to be received by devices, such as modems at the various homes **102**, and to receive upstream communications from those modems on one or more upstream frequencies. The local office **103** may also include one or more network interfaces **108**, which can permit the local office **103** to communicate with various other external networks **109**. These networks **109** may include, for example, networks of Internet Protocol devices, telephone networks, cellular telephone networks, fiber optic networks, local wireless networks (e.g., WiMAX), satellite networks, and any other desired network, and the interface **108** may include the corresponding circuitry needed to communicate on the network **109**, and to other devices on the network such as a cellular telephone network and its corresponding cell phones, or other network devices. For example, the network **109** may communicate with one or more content sources, such as multicast or unicast video sources, which can supply video streams for ultimate consumption by the various client devices in the homes **102**.

As noted above, the local office **103** may include a variety of servers **105-107** that may be configured to perform various functions. For example, the local office **103** may include a push notification server **105** that can generate push notifications to deliver data and/or commands to the various homes **102** in the network (or more specifically, to the devices in the homes **102** that are configured to detect such notifications). The local office **103** may also include a content server **106** configured to provide content to users in the homes. This content may be, for example, video on demand movies, television programs, songs, text listings, etc. The content server may include software to validate user identities and entitlements, locate and retrieve requested content, encrypt the content, and initiate delivery (e.g., streaming) of the content to the requesting user and/or device.

The local office **103** may also include one or more application servers **107**. An application server **107** may be a computing device configured to offer any desired service, and may run various languages and operating systems (e.g., servlets and JSP pages running on Tomcat/MySQL, OSX, BSD, Ubuntu, Redhat, HTMLS, JavaScript, AJAX and COMET). For example, an application server **107** may be used to implement a cache server for the content found on the content server **106**. Other example application servers may be responsible for collecting data such as television program listings information and generating a data download for electronic program guide listings. Another application server may be responsible for monitoring user viewing habits and collecting that information for use in selecting advertisements. Another application server may be responsible for formatting and inserting advertisements in a video stream being transmitted to the homes **102**. And as will be discussed in greater detail below, another application server may be responsible for receiving user remote control commands, and processing them to provide an intelligent remote control experience.

An example home **102***a* may include an interface **120**. The interface **120** may comprise a device **110**, such as a modem, which may include transmitters and receivers used to communicate on the links **101** and with the local office **103**. The device **110** may be, for example, a coaxial cable modem (for coaxial cable links **101**), a fiber interface node (for fiber optic links **101**), or any other desired device having similar functionality. The device **110** may be connected to, or be a part of, a gateway interface device **111**. The gateway interface device **111** may be a computing device that communicates with the device **110** to allow one or more other devices in the home to communicate with the local office **103** and other devices beyond the local office. The gateway **111** may be a set-top box (STB), digital video recorder (DVR), computer server, or any other desired computing device. The gateway **111** may also include local network interfaces (not shown) to provide communication signals to devices in the home, such as televisions **112**, additional STBs **113**, personal computers **114**, laptop computers **115**, wireless devices **116** (wireless laptops and netbooks, tablet computers, mobile phones, mobile televisions, personal digital assistants (PDA), etc.), and any other desired devices. Examples of the local network interfaces include Multimedia Over Coax Alliance (MoCA) interfaces, Ethernet interfaces, universal serial bus (USB) interfaces, wireless interfaces (e.g., IEEE 802.11), Bluetooth interfaces, and others. Any of the devices in the home, such as the gateway **111**, STB **113**, computer **114**, etc., can include an application software client that can make use of the video images captured by the image capture servers.

FIG. **2** illustrates general hardware elements, software elements, or both that can be used to implement any of the various computing devices and/or software discussed herein. The computing device **200** may include one or more processors **201**, which may execute instructions of a computer program to perform any of the features described herein. The instructions may be stored in any type of computer-readable medium or memory, to configure the operation of the processor **201**. For example, instructions may be stored in a read-only memory (ROM) **202**, random access memory (RAM) **203**, removable media **204**, such as a Universal Serial Bus (USB) drive, compact disk (CD) or digital versatile disk (DVD), hard drive, floppy disk drive, or any other desired electronic storage medium. Instructions may also be stored in an attached (or internal) hard drive **205**. The computing device **200** may include one or more output devices, such as a display **206**, such as an external monitor or television, and may include one or more output device controllers **207**, such as a video processor. There may also be one or more user input devices **208**, such as a remote control, keyboard, mouse, touch screen, microphone, etc. The computing device **200** may also include one or more network interfaces, such as input/output (I/O) interface **209** (e.g., a network card) to communicate with an external network **210**. The network interface may be a wired interface, wireless interface, or a combination of the two. In some embodiments, the interface **209** may include a modem (e.g., a cable modem), and network **210** may include the communication links **101** discussed above, the external network **109**, an in-home network, a provider's wireless, coaxial, fiber, or hybrid fiber/coaxial distribution system (e.g., a DOCSIS network), or any other desired network.

Various features described herein offer improved remote control functionality to users accessing content from the local office **103** or another content storage facility or location. For example, one such user may be a viewer who is watching a television program being transmitted from the local office **103**. In some embodiments, the user may be able to control his/her viewing experience (e.g., changing channels, adjusting volume, viewing a program guide, etc.) using any networked device, such as a cellular telephone, personal computer, personal data assistant (PDA), netbook computer, etc., aside from (or in addition to) the traditional infrared remote control that may have been supplied together with a television or STB.

FIG. **3***a* illustrates an example distribution hierarchy of computing devices, such as caching servers for an example content delivery network (CDN). The hierarchy of caching servers may be used to help with the distribution of content (e.g., online content) by servicing requests for that content on behalf of the content's source. At the top of the hierarchy is origin server **300**. The origin server **300** may be a server that provides one or more pieces of content of a content provider. For example, origin server **300** may be implemented using content server **206** of FIG. **2**, and can supply a variety of content to requesting users and devices. The content may be, for example, movies or other data available for on demand access by clients (not shown), and the origin server **300** for a movie may be a server that has access to a copy of the movie or initially makes the movie available. Although FIG. **3***a* illustrates a single origin server **300** for a given distribution hierarchy, multiple origin servers may be used for the given distribution hierarchy.

The origin server **300** may also establish the caching hierarchy that will be used to distribute content. For example, the server **300** may transmit messages to one or more cache servers, requesting that the cache servers assist in caching the origin server's content, and instructing the cache server as to where that cache server should be in the hierarchy for the origin's content domain(s), what domain(s) of content it should (or should not) cache, access restrictions, authentication requirements for granting access, etc.

To facilitate distribution of the content, one or more top level cache servers **301***a-b* can be communicatively coupled to the origin server **300**, and each can store a copy of the file(s) containing the content of the origin server **300** (e.g., a copy of the movie files for an on-demand movie). These top level servers can be co-located at the same premises as the origin server **300** and implemented as application servers **107**, or they can be located at locations remote from the origin server **300**, such as at a different local office connected to the network **109**. The top level cache servers **301***a-b* may also receive and respond to client requests for the content. Further down in the hierarchy may be one or more intermediate level cache servers **302***a-c* and edge cache servers **303***a-d*, and these may be implemented using the same hardware as the cache servers **301***a-b*, and can be configured to also receive and respond to client requests for content. Additional layers of caches in the hierarchy may also be used as desired, and the hierarchical arrangement allows for the orderly distribution of the content, updates to the content, and access authorizations. For example, lower level servers may rely on higher lever servers to supply source files for the content and to establish access authorization parameters for the content. In some embodiments, the top and intermediate level servers may refrain from interaction with clients, and may instead limit their content delivery communications to communicating with other servers in the distribution network. Limiting client access to just the lowest level, or edge, servers can help to maintain security and assist with scaling.

The CDN may also include one or more service routers **304**, which may be communicatively coupled to all of the cache servers, but which need not be a part of the caching hierarchy. The service router **304** may facilitate communications between the members of the hierarchy, allowing them to coordinate. For example, the servers in the hierarchy may periodically transmit announcement messages to other cache servers, announcing their respective availabilities (e.g., announcing the content that they are able to provide, or the address domains or routes that they support). In some embodiments, the caches may simply transmit a single announcement to a service router **304**, and the service router **304** may handle the further distribution of the announcement messages to other servers in the hierarchy. In this manner, the service router **304** may act as a route reflector in a border gateway protocol, reducing the amount of traffic passing directly between the caches.

FIG. **3***a* illustrates a logical hierarchy for a given content delivery network, from its origin **300** (e.g., a server storing the original copy of a particular video asset) down through layers of caches. Each individual piece of content can have its own hierarchy, however, and a single server (e.g., a computing device) can play different roles in the hierarchies for different pieces of content. So, for example, while a first computing device can act as the origin **300** for a first piece of content (e.g., videos from "ESPN.COM"), that same device can act as an intermediate-level cache **302***b* for a different piece of content (e.g., videos from "NBC.COM").

For some aspects of the disclosure, the physical arrangement of the servers need not resemble FIG. **3***a* at all. As illustrated in FIG. **3***b*, each of the cache servers may be coupled through its own corresponding router **305** to one or more communication network(s). The routers **305** may contain the necessary routing tables and address information to transmit messages to other devices on the network, such as the other caches, client devices, etc.

FIG. **4** illustrates an example timeline for a streamlined content delivery technique (e.g., a streamlined HTTP enhancement proxy content delivery technique), in which content is requested and delivered between a client device (e.g., device **200** shown in FIG. **2**, gateway device **111** shown in FIG. **1**), a server (e.g., device **200** shown in FIG. **2**, edge cache server **303** shown in FIG. **3**), and a remote server (e.g., device **200** shown in FIG. **2**, intermediate level cache server **302** shown in FIG. **3**). While a client device and a server are shown in the example streamlined HTTP enhancement proxy content delivery timeline of FIG. **4**, the technique may also be used for content delivery among servers, such as server **303** and server **302** shown in FIG. **3**, which may or may not be part of the same content delivery network.

As illustrated in FIG. **4**, data transmissions as a function of time are shown for the client device and the remote server. Data received by the client device (e.g., "Client Device RX") is illustrated as the portion of FIG. **4** below line **451**. Data transmission by the client device (e.g., "Client Device TX") is illustrated as the portion of FIG. **4** above line **451** and below line **452**. Data received by the server (e.g., "Server RX") is illustrated as the portion of FIG. **4** above line **452** and below line **453**. Data transmission by the server (e.g., "Server TX") is illustrated as the portion of FIG. **4** above line **453**. Data receipt and transmission by additional servers, such as remote cache or origin servers, are not shown for the sake of brevity.

The client device may transmit content request **401** at time **402** to a server, for example, in response to a user requesting content using an input device (e.g., input device **200** shown in FIG. **2**). Content request **401** may be, for example, an HTTP GET request for a video asset (e.g., a particular movie or program from a website) or a fragment of the video asset. The content fragment may be, for example, any time-based data unit of arbitrary size, such as a two-second video fragment of the user-requested movie or program. In some embodiments, content request **401** may be an HTTP request for a data unit. The data unit may be, for example, a defined unit of content, such as a high definition video asset, a three-dimensional video asset, a two-second video fragment, or any other suitable content or content fragment provided using an HTTP protocol.

Content request **401** may be transmitted by the client device using any suitable transmission device or network, such as network I/O interface **209** shown in FIG. **2**, over any suitable communications path or network, such as network **210** shown in FIG. **2**, using any suitable communications or network protocol. For example, the client device may open a network protocol session, such as a transmission control protocol (TCP) session or a user datagram protocol (UDP) session, with the server. In another example, content request **401** may be transmitted by the client device to an intermediate device (e.g., modem **110** shown in FIG. **1**, interface **104** shown in FIG. **1**, network I/O **209** interface shown in FIG. **2**, service router **304** shown in FIG. **3**, etc.) communicatively coupled between the client device and the server.

In some embodiments, content request **401** may include an address identifier of the client device making the request. The address identifier may contain routing information to indicate how the client device can be contacted. For example, the address identifier may be a dotted-decimal internet protocol (IP) address for the client device or an intermediate device that handles the client device's communications.

In some embodiments, content request **401** may include a uniform resource identifier (URI). For example, content request **401** may include the URI:

"http://www.videocontent.com/tv/NCIS/11915/12128607/Restless/videos"

corresponding to user request for an episode of the television program NCIS. In another example, content request **401** may include the URI:

"http://videocontent.net/movies/Avatar/140880/full-movie"

corresponding to a user request for the motion picture Avatar.

In some embodiments, content request **401** may include a URI prefix, such as "videocontent/tv/NCIS/videos" or "videocontent/movies/Avatar/full-movie", to identify a domain or subdomains of the requested content. Although the example URI prefixes use text and the forward slash "/" to indicate sub-domain relationships, other forms of notation may be used. For example, the domain name can be represented in an order that increases in specificity from left to right, such as "net. videocontent.tv.ncis" or "net. videocontent.movies.avatar," or vice versa. In some embodiments, a fully qualified domain name (FQDN) can be used as a URI prefix. For example, the URI prefix may be the FQDN "videocontent.net." or any other suitable FQDN or domain name associated with content request **401**.

In some embodiments, the URI prefix can be provided in a shortened form to reduce code bloat. For example, a URI prefix for the movie Avatar could simply be "videocontentavatar."

In some embodiments, content request **401** may include a time duration, a data range, or both corresponding to a fragment of the requested content (e.g., a two-second fragment of requested video content). For example, content request **401** may include a URI appended with the time duration "#t=2,4" corresponding to a two-second video fragment for seconds 2-4 of the requested content. In another example, content request **401** may include the data range "bytes=6000001-12000000" corresponding to the two-second video fragment for seconds 2-4 of a video with an associated data rate of approximately 3 MB/s.

In some embodiments, content request **401** may include or be associated with a timeout, such as timeout **413**. Timeout **413** may correspond to a time duration after which the requesting client will respond as if an error has occurred with the original request, and may occur at a specified time after request **401** has been transmitted by the client device. In certain embodiments, a timeout period may correspond to the amount of time between request time **402** and timeout **413**. For example, timeout **413** may occur two seconds after request time **402** in association with a two-second timeout period. If the requested content is not received by the client device before the timeout period ends, content request **401** may timeout and transmission of an additional request may begin (e.g., possibly for the requested content at a lower quality or bit rate). If the additional request also times out, the client device's request for content may become abandoned.

The server may receive content request **403** at time **404** from the client device using any suitable receiver device, such as network I/O interface **209** shown in FIG. **2**. Content request **403** may be substantially the same as, or a modified version of, content request **401** transmitted by the client device. For example, content request **403** may contain transmission errors (e.g., noise, jitter, etc.) resulting from, for example, the electromagnetic interference in the transmission medium between the client device and the server. In another example, content request **403** may be received from an intermediate device communicatively coupled between the client device and the server. In some embodiments, content request **403** may be received from another server. For example, content request **403** may be received at a higher-level (parent) cache server or origin server from a lower-level (child) cache server.

In some embodiments, the server may check to determine whether it possesses or stores the requested content in its cache memory (e.g., ROM **202**, RAM **203**, removable media **204**, or hard drive **205** shown in FIG. **2**), using any suitable technique or circuitry (e.g., processor **201** shown in FIG. **2**). For example, the server may decode request **403** to identify the address information (e.g., URI, URI prefix) of the requested content and perform a search of its memory based on the identified address information. If the requested content is stored in its memory, the server can begin transmitting the requested content to the requesting client (or server), which is not shown for the sake of brevity. If it is not, the server can transmit content request **405** to another server, such as a parent cache server or origin server.

The server may transmit content request **405** at time **406** to a remote server, such as a higher-level cache server or origin server, in response determining that the requested content is not stored in its memory. For example, content request **405** may be an HTTP GET request for the requested video asset or a fragment of the video asset. Content request **405** may be transmitted by the server using any suitable transmission device, such as network I/O interface **209** shown in FIG. **2**, over any suitable communications path or network, such as network **210** shown in FIG. **2**. For example, the server may open a network protocol session with the remote server. In some embodiments, request **405** may be sent to a router (e.g., service router **304** shown in FIG. **3**) for redistribution to other servers in the CDN hierarchy.

In some embodiments, request **405** may include an address identifier of the server making the request. This identifier can contain routing information to indicate how the server can be contacted. This address can be, for example, a dotted-decimal internet protocol (IP) address for the server, or for a router, modem, or network interface that handles the server's communications.

In some embodiments, the server may identify the remote server to which content request **405** will be transmitted using any suitable server selection technique, path selection technique, or both. For example, the server may consult an index of cache servers (e.g., an index or database maintained by service router **304** shown in FIG. **3**) to determine what next higher level cache server should service the request. The cache server index may identify, for example, cache destinations for each listed domain as indicated by its URI or URI prefix. The cache server index may also provide path information for obtaining the domain's content when servicing a client request for the content.

In some embodiments, various other factors may be used in the identification and selection of the remote server to which request **405** is to be directed. One factor may be the processing capability of the remote server. For example, a remote server with a faster processing capability may be preferred over a remote server with a slower processing capability. Another factor may be the length of a physical connection between the server and the remote server. The length may include the number of intermediate routers and network legs, and the path selection process may prefer a shorter path. For example, a remote server located in the same domain or CDN may be preferred over a remote server located in a different domain or CDN. Another factor may be the cost (e.g., financial cost, computing cost, time cost) associated with accessing the respective caches. For example, the path selection process conducted by the cache server on the index may select the least costly route. In some embodiments, other business rules, processes, or techniques may be used for sever selection, path selection, or both.

The server may receive content **407** at time **408** from the remote server or from an intermediate device using any suitable receiver device. In some embodiments, the server may initially receive portion **420** of content **407**. Portion **420** may be, for example, a portion of the data unit requested by the client device. Portion **420** may be of an arbitrarily small size. For example, portion **420** may be the first 64 bits of a 6 MB video fragment. In some embodiments, the server may store or buffer portion **420** in a temporary storage device (e.g., RAM **204** shown in FIG. **2**). In some embodiments, the server may store portion **420**, the entire amount of content **407**, or both in its cache memory.

In some embodiments, the server may identify the portion or portions of the data unit that it has received. For example, the server may store information identifying the portions of the data unit that have been received. In certain implementations, the server may associate a flag with an index of the data unit. The server may analyze the flag data to determine whether one or more of the portions of the data unit have been received. The server may also, for example, use the flag data to determine whether any portions of a requested data unit are stored in the server's memory. If the server determines that one or more of the portions are stored locally, it may transmit the locally-stored portions to the requesting client device and request additional portions of the data unit from any suitable remote server or content delivery network.

The server may begin transmitting portion **421** of content **409** at time **410** to the requesting client device (e.g., by opening a network protocol session with the client device) upon receiving and buffering portion **420** of content **407**. For example, the difference between time **408** and time **410** may be arbitrarily small and limited only by system capabilities. Portion **421** may be substantially the same as, or a modified version of, portion **420**. In some embodiments, portion **421** may correspond to data read from a buffered version of portion **420** stored in the server's memory. For example, the size of portion **421** may correspond to the smallest bufferable data unit. In another example, the size of portion **421** may correspond to a maximum transmission unit (MTU).

In some embodiments, the transmission of portion **421** begins in advance of completely receiving content **407** because waiting to completely receive content **407** at time **414** may result in transmission of content **407** beginning after timeout **413** has occurred. In some embodiments, the server may begin a looping process to receive, buffer, and transmit subsequent portions of content **407** until all portions of content **407** have been received. For example, the looping process may proceed until an end of transmission character (EOT) in content **407** has been received and decoded (if needed) by the server.

The client device may receive portion **422** of content **411** at time **412** from the server using any suitable receiver device, such as network I/O interface **209** shown in FIG. **2**. Portion **422** may be substantially the same as, or a modified version of, content **421** transmitted by the server. As illustrated in the example streamlined HTTP enhancement proxy content delivery timeline of FIG. **4**, the client device receives portion **422** before timeout **413** and timeout **413** may be avoided.

In some embodiments, the client device may present the received content for display on a display device (e.g., television **112**, personal computer **114**, laptop computer **115**, wireless device **116** shown in FIG. **1**, display **206** shown in FIG. **2**) once it has received all of content **411**. If content **411** is a content fragment, the client device may begin a looping process to request the next content fragment of the user requested content. For example, the client device may begin a looping process after decoding an EOT in content **411** to request the next two-second video fragment of the movie or high-definition television program requested by the user. The looping process may proceed by requesting subsequent content fragments until all content fragments of the user requested content have been received.

FIG. **5** illustrates an example process flow for providing content using a streamlined HTTP enhancement proxy content delivery technique.

In step **501**, the server receives an HTTP request for a data unit from a client device, such as content request **401** shown in FIG. **4**. The data unit may be, for example, a user-requested video asset or a fragment of the user-requested video asset. The request may include address information (e.g., URI, URI prefix) to identify the requested data unit. In some embodiments, the request may be received from an intermediate device or from another cache server.

In step **502**, the server determines whether its memory contains a copy of the requested data unit based on address information or other identifying information extracted from the received request. If the server determines that its memory includes a copy of the requested data unit, the process proceeds to step **503**. If the server determines that its memory does not include a copy of the requested data unit, the process proceeds to step **504**.

In step **503**, the server returns a copy of the requested data unit to the requesting client device in response to determining that the data unit was found in the server's memory. For example, the server may return the entire data unit requested by the client device.

In step **504**, the server transmits a request for the data unit to a remote server, such as request **403** shown in FIG. **4**. In some embodiments, the server may transmit the request an origin or cache server identified using any suitable server selection technique, path selection technique, or both. For example, the server may search a cache server index using a longest match lookup routine to identify the best matching remote server that supports the data unit. If a match is found, then the longest match can be used to generate the request (e.g., request **405** shown in FIG. **4**) to the identified remote server.

In step **505**, the server begins to receive a portion of the data unit from the remote server, such as portion **420** of content **407** shown in FIG. **4**. During receipt of the requested data unit, the server may proceed to step **506** and transmit a portion of the data unit (e.g., portion **421** of content **409**) to the client device even though the entire data unit has not been fully received. For example, the server may transmit a fraction of a requested two-second video fragment to the client device as soon as it is received, limited only by the server's performance capabilities. The transmission size may be arbitrarily small, or may be based on an MTU, smallest bufferable data unit, or other suitable parameter. In certain implementations, the transmission may begin as soon as the server receives the portion of the data unit. In certain implementations, if the MTU buffer is filled before the server receives the entire portion of the data unit, the transmission may begin as soon as the MTU buffer is filled.

In step **507**, the server determines whether it has received the entire data unit (e.g., by decoding an EOT in content **407** shown in FIG. **4**). If the cache server determines that it has not received the end of the data unit, the process returns to step **505**. If the cache server determines that it has received the end of the data unit, the process ends.

With the features described above, various advantages may be achieved. An advantage of the present technique is that timeout of the request is avoided in some instances as a result of transmission by the server of an initial portion of the content beginning before the entire requested content has been received at the server (e.g., before timeout has occurred). As a result, a user can request and receive high quality (e.g., high bit rate) videos using an HTTP protocol without, in some instances, the user's client device experiencing timeout. Another advantage of the present technique is that delay in the delivery of content in a CDN is reduced because data is transmitted to the next layer in the CDN hierarchy as soon as or shortly after it is received. Accordingly, the network is not overloaded with redundant content requests and the user's viewing experience is enhanced.

The various features described above are merely nonlimiting examples, and can be rearranged, combined, subdivided, omitted, and/or altered in any desired manner. For example, features of the servers can be subdivided among multiple processors and computing devices. The true scope of this patent should only be defined by the claims that follow.

The invention claimed is:

1. A method comprising:

receiving, by a computing device from a user device, a request for content, wherein a first portion of the content is stored at the computing device;

based on an expiration period of the request and prior to receiving a second portion of the content, sending, by the computing device to the user device, the first portion of the content; and

after receiving the second portion of the content, sending, by the computing device to the user device, the second portion of the content.

2. The method of claim **1**, wherein the request for the content indicates the expiration period, and

wherein the expiration period comprises a time period beginning with a time that the request was sent by the user device.

3. The method of claim **1**, wherein the sending the second portion of the content comprises sending the second portion of the content after the expiration period.

4. The method of claim **1**, further comprising:

terminating, after determining that the first portion of the content was not received by the user device within the expiration period, servicing of the request.

5. The method of claim **1**, wherein the expiration period comprises a quantity of time that the user device will wait before resending the request for the content.

6. The method of claim **1**, wherein the expiration period is based on an indication of a time duration associated with the content.

7. The method of claim **1**, wherein the sending the first portion of the content is further based on determining that the first portion of the content comprises a maximum transmission unit (MTU) of content.

8. The method of claim **1**, wherein the expiration period comprises a quantity of time that the user device will wait before terminating the request.

9. The method of claim **1**, wherein the request comprises a request for the content in a first content quality, and

wherein the expiration period comprises a quantity of time that the user device will wait before sending a second request for the content in a second content quality different than the first content quality.

10. An apparatus comprising:

one or more processors; and

memory storing instructions that, when executed by the one or more processors, cause the apparatus to:

receive, from a user device, a request for content, wherein a first portion of the content is stored at the apparatus;

based on an expiration period of the request and prior to receiving a second portion of the content, send the first portion of the content to the user device; and

after receiving the second portion of the content, send, to the user device, the second portion of the content.

11. The apparatus of claim **10**, wherein the request for the content comprises the expiration period, and

wherein the expiration period comprises a time period beginning with a time that the request was sent by the user device.

12. The apparatus of claim **10**, wherein the instructions, when executed by the one or more processors, cause the apparatus to send the second portion of the content by sending the second portion of the content after the expiration period.

13. The apparatus of claim **10**, wherein the expiration period is based on an indication of a time duration associated with the content.

14. The apparatus of claim **10**, wherein the instructions, when executed by the one or more processors, further cause the apparatus to:

terminate, after determining that first portion of the content was not received by the user device within the expiration period, servicing of the request.

15. The apparatus of claim **10**, wherein the expiration period comprises:

a quantity of time that the user device will wait before resending the request; or

a quantity of time that the user device will wait before terminating the request.

16. The apparatus of claim **10**, wherein the instructions, when executed by the one or more processors, cause the apparatus to send the first portion of the content further based on determining that the first portion of the content comprises a maximum transmission unit (MTU) of content.

17. The apparatus of claim **10**, wherein the request comprises a request for the content in a first content quality, and

wherein the expiration period comprises a quantity of time that the user device will wait before sending a second request for the content in a second content quality different than the first content quality.

18. A non-transitory computer readable medium storing instructions that, when executed, cause:

receiving, from a user device, a request for content;

based on an expiration period of the request and prior to receiving a second portion of the content, sending a first portion of the content to the user device; and

after receiving the second portion of the content, sending, to the user device, the second portion of the content.

19. The non-transitory computer readable medium of claim **18**, wherein the request for the content comprises the expiration period, and

wherein the expiration period comprises a time period beginning with a time that the request was sent by the user device.

20. The non-transitory computer readable medium of claim **18**, wherein the instructions, when executed, cause sending the second portion of the content by causing sending the second portion of the content after the expiration period.

21. The non-transitory computer readable medium of claim **18**, wherein the instructions, when executed, further cause:

terminating, after determining that the first portion of the content was not received by the user device within the expiration period, servicing of the request.

22. The non-transitory computer readable medium of claim **18**, wherein the expiration period comprises:

a quantity of time that the user device will wait before resending the request;

or

a quantity of time that the user device will wait before terminating the request.

23. The non-transitory computer readable medium of claim **18**, wherein the instructions, when executed, cause sending the first portion of the content further based on determining that the first portion of the content comprises a maximum transmission unit (MTU) of content.

24. The non-transitory computer readable medium of claim **18**, wherein the expiration period is based on an indication of a time duration associated with the content.

25. The non-transitory computer readable medium of claim **18**, wherein the request comprises a request for the content in a first content quality, and

wherein the expiration period comprises a quantity of time that the user device will wait before sending a second request for the content in a second content quality different than the first content quality.

26. A system comprising:

a computing device; and

a user device,

wherein the computing device comprises:

one or more first processors; and

memory storing first instructions that, when executed by the one or more first processors, cause the computing device to:

receive, from the user device, a request for content, wherein a first portion of the content is stored at the computing device;

based on an expiration period of the request and prior to receiving a second portion of the content, send, to the user device, the first portion of the content; and

after receiving the second portion of the content, send, to the user device, the second portion of the content, and

wherein the user device comprises:

one or more second processors; and

memory storing second instructions that, when executed by the one or more second processors, cause the user device to:

send, to the computing device, the request; and

receive, from the computing device, the first portion and the second portion of the content.

27. The system of claim **26**, wherein the request for the content comprises the expiration period, and

wherein the expiration period comprises a time period beginning with a time that the request was sent by the user device.

28. The system of claim **26**, wherein the first instructions, when executed by the one or more first processors, cause the computing device to send the second portion of the content by sending the second portion of the content after the expiration period.

29. The system of claim **26**, wherein the expiration period is based on:

an indication of a time duration associated with the content.

30. The system of claim **26**, wherein the first instructions, when executed by the one or more first processors, further cause the computing device to:

terminate, after determining that first portion of the content was not received by the user device within the expiration period, servicing of the request.

31. The system of claim **26**, wherein the expiration period comprises:

a quantity of time that the user device will wait before resending the request; or

a quantity of time that the user device will wait before terminating the request.

32. The system of claim **26**, wherein the first instructions, when executed by the one or more first processors, cause the computing device to send the first portion of the content further based on determining that the first portion of the content comprises a maximum transmission unit (MTU) of content.

33. The system of claim **26**, wherein the request comprises a request for the content in a first content quality, and

wherein the expiration period comprises a quantity of time that the user device will wait before sending a second request for the content in a second content quality different than the first content quality.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 11,356,491 B2
APPLICATION NO. : 16/233788
DATED : June 7, 2022
INVENTOR(S) : Chen

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Specification

Column 4, Detailed Description, Line 17:
Delete "HTMLS," and insert --HTML5,-- therefor

Column 10, Detailed Description, Line 13:
Delete "204" and insert --203-- therefor

In the Claims

Column 14, Line 10:
In Claim 22, after "request;", delete "¶"

Signed and Sealed this
Twenty-second Day of August, 2023

Katherine Kelly Vidal

Katherine Kelly Vidal
Director of the United States Patent and Trademark Office